While in each case the real acidity of the lot coagulating with alcohol and curdling in sterilization is higher, the difference is so small that it is very doubtful if it would more than counteract the effect of the higher solids of the corresponding lot.

CONCLUSIONS.

1. The acid test as ordinarily used will reject a portion of the unsatisfactory milks, but as a whole it is unreliable and inadequate as a means of determining the quality of milk for condenseries where evaporated milk is manufactured.

2. There is no direct relation between the coagulation of milk with alcohol and its titratable acidity, but milks high in titratable acidity as a result of fermentation will in the large majority of cases show coagulation with alcohol.

3. The alcohol test shows good possibilities as a practical and reliable test for determining the quality of milk for condenseries making evaporated milk. How generally the test can be applied will require further investigation at other condenseries. It is believed that it can be used to advantage in a large majority of average factories.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 945

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER May 27, 1921

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By

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CONTENTS.

DAIRY PRACTICES AT THE GOVERNMENT FARM AT BELTSVILLE.[1]

Opportunities for observing the effects of the feed on milk secretion have been rather favorable on the dairy experimental farm at Beltsville, Md., where the authors are stationed. Since 1912 a herd of from 50 to 100 cows, some of which are purebred Guernseys, Jerseys, or Holsteins, and some grades, has been maintained here. Daily records have been kept of the milk yields throughout, and yearly records of the feed consumed up to 1918. Since 1918 monthly or daily records of the rations have been kept. The fat in the milk of each cow has been determined once a month, and from the results so obtained the monthly and yearly yields of fat have been calculated. The feeds chiefly used have been corn meal, wheat bran, cottonseed

[1] The authors wish to acknowledge the valuable services of H. J. Nedrow, H. T. Converse, and W. E. Benscoter. Messrs. Nedrow and Converse were the herdsmen at the Beltsville farm during the period when the experiments were carried out, and they supervised the feeding and care of the experimental animals. Mr. Benscoter was responsible for the feeding in a number of cases, and carried out this part of the work with unusual care and accuracy.

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meal, linseed meal, alfalfa and other legume hays, and corn silage and stover. Most of the cows have had a little pasture in the summer, but not enough to make up any considerable proportion of the total amount of feed eaten in the year.

The aim has been to feed the cows as much protein as is required by the most liberal of the American feeding standards, to keep them in good condition, to have them calve once a year, and to have them dry each year for 6 to 8 weeks before calving. It has generally happened in practice that the cows were fed a little less liberally than is demanded by the Savage and Eckles standards (9)[2] for the first two or three months after calving, and a little more liberally later. When they were dry they were usually fed 4 pounds of grain mixture B,[3] 4 pounds of legume hay, and as much silage as they would clean up. When the hay was alfalfa and the amount of silage eaten daily 30 pounds, which was the most usual state of things, this ration provided 1.29 pounds of digestible crude protein and 10.29 pounds of total digestible nutriment daily. After subtracting the maintenance requirement for a 1,000-pound cow, this would allow 0.59 pound protein and 2.37 pounds total nutriment daily for the growth of the unborn calf, which, according to the results obtained by Eckles (3), ought to be sufficient.

We have recently calculated the protein and total nutriment in the yearly rations of a number of cows from the general herd and have compared these quantities with those required for their maintenance and for their milk and fat yield according to the Savage standard. The results have shown that the cows usually received rations a little more liberal than those demanded by that standard.

During the last two years a number of the purebred Holsteins have been run on official test. In order to increase their milk yield their rations were made decidedly more liberal than those called for by any of the feeding standards. During the milking period they received daily about 12 pounds of alfalfa hay, 20 pounds of corn silage, and as much grain as they could clean up without getting sick; they usually ate 18 to 20 pounds a day of grain mixture F. They were fed heavily also before their calves were born; for 60 days or more before calving they usually received about 15 pounds of grain mixture F, 12 pounds of alfalfa hay, and 25 pounds of corn silage, a ration containing approximately four times as much protein and two and one-half times as much total nutriment as the routine ration fed to the dry cows of the general herd.

The cows on test gave from 15,000 to 20,000 pounds of milk in the year; that is, three to four times as much as most of the cows in the general herd. A part of this larger yield is due to the fact that

[2] The figures in parentheses refer to "Literature cited" at end of paper.

[3] See list of grain mixtures used in experiments, on p. 25.

the test cows were better bred, but a part also is due to the larger quantity of feed they consumed. How much of the increased milk yield to attribute to each of these factors is a question of great practical interest.

STANDARD RATIONS INSUFFICIENT FOR OPTIMUM MILK YIELD.

The cycle of lactation consists of two phases which may be called the preparatory and the active phases. Considerable changes go on in the udder of a cow for some time before her calf is born, and usually make themselves manifest by an increase in size and congestion of that organ. There is no doubt that the amount of the subsequent milk yield largely depends on these changes, and it is highly probable that the changes themselves depend on the state of nutrition in which the animal happens to be for the few weeks before her calf is born.

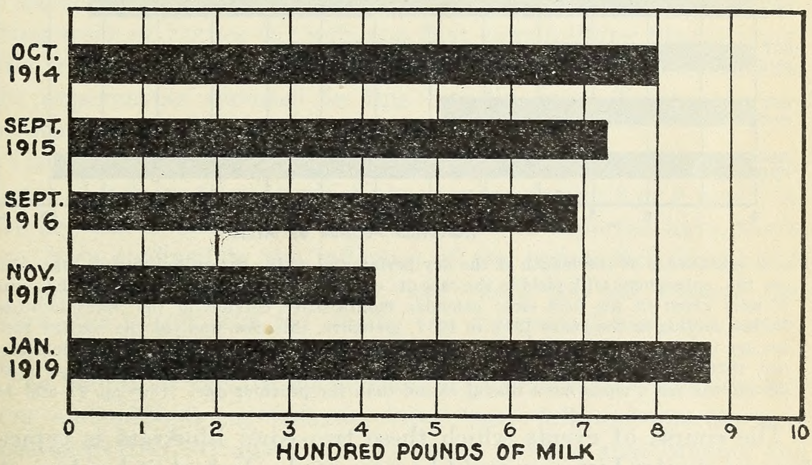

FIG. 1.—Influence of the length of the dry period on the subsequent milk yield in the case of cow 17. The columns represent the pounds of milk given in the first clear calendar month after calving in the years indicated. Before calving in the years 1914 to 1917, inclusive, this cow was fed the routine ration for dry cows at Beltsville; her dry periods averaged 44 days. Before calving, in December, 1918, she was given a dry period of 122 days and fed approximately as in her previous dry periods.

It is well known that animals are capable of storing up large quantities of nutritive material in times of plenty and using these stores in times of stress. The effect of the feed on milk secretion, therefore, often may be long delayed and rather complicated. It is not at all impossible that the effects of a deficient ration supplied in one lactation period may not show themselves until the subsequent period or even later.

Figures 1 and 2 give graphically the histories of two cows which were brought to the Beltsville farm some years ago and fed and treated according to the usual routine. The milk yields fell off very

noticeably during the routine treatment. After several years of the routine treatment cow 17 was given an unusually long dry period before calving, and cow 201, a more liberal ration for some weeks before calving. In both cases the subsequent milk yields were markedly increased. (See p. 13.)

The increase in the milk yields of these cows is due in the one case to the more liberal ration supplied before the calf was born; and in the other to the long dry period with a supermaintenance ration. The rations fed after calving bore about the same relation to the milk yield as they had in previous years. It may be added that the milk yield for the first few weeks of lactation is not very closely dependent on the contemporaneous food supply (2).

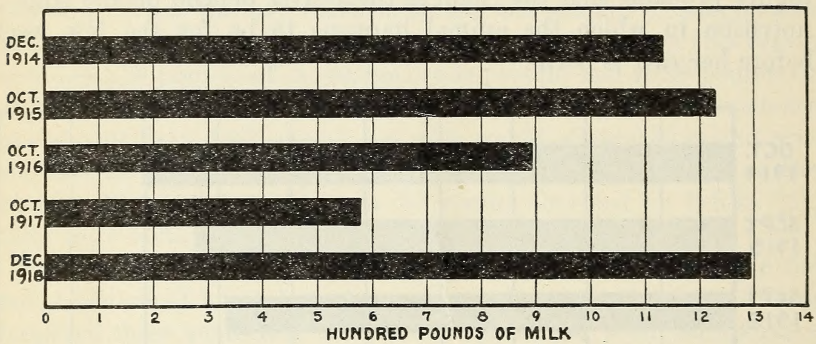

FIG. 2.—Influence of the length of the dry period and of the ration fed during that period on the subsequent milk yield in the case of cow 201. The columns represent the pounds of milk given in the first clear calendar month after calving in the years indicated. Before calving in the years 1914 to 1917, inclusive, this cow was fed the routine ration for dry cows at Beltsville; her dry periods averaged 50 days. Before calving in December, 1918, she was given a dry period of 78 days, and during the last 40 days of this period was fed a much more liberal ration than the previous one. (See pp. 13 and 14.)

The course of events which these two cows illustrate is typical. Several similar histories could be presented. Indeed, it has been the rule on this farm that greatly increased milk yields were obtained when cows from the general herd were dried off two months or more before they were due to calve and fed liberally during the dry period. Cows 17 and 201 were selected as examples, not because the downhill course of their milk yields on the routine treatment was particularly rapid or the subsequent recoveries particularly marked, but simply because they had been freer from disease and from disturbing experiments during their stay at Beltsville than others which might have been selected. It is, therefore, a very moderate statement of the case to say that average and high-producing cows often do not maintain anything like their optimum milk yield when they are bred to calve once a year and fed for several years approximately according to the most liberal of the American feeding standards, even

though they may get a little pasture in addition.[4] Under this treatment the milk yield may be reduced, after a few years, to less than half the optimum; and when it has been so reduced it may be very greatly increased by liberal feeding during a 2-months' dry period.

A point of great interest to be noted in the history of cow 201 is the length of time which it took for the full effect of the routine method of feeding to become apparent. The milk yield did not reach its lowest point until she had been on the farm for four years.

NATURE OF THE DEFICIENCY IN THE ROUTINE RATIONS FED AT BELTSVILLE.

It is probable that the rations fed at Beltsville were not deficient in a general sense, but deficient only in one or a few particular constituents necessary for milk secretion. The cows were kept in good general condition, which seems to indicate that they received enough of the energy-yielding portion of the ration. The recent very interesting work of Forbes (5) indicates that cows milking liberally may often receive insufficient calcium and phosphorus in their rations. The experiments reported in this bulletin were directed toward throwing more light on that question.

There is no doubt that a cow's milk yield may be markedly influenced by the nutriment which she receives during 6 or 8 weeks before her calf is born. The experiments to be reported have, therefore, been confined to the influence of the ration fed during this period on the subsequent milk yield; and, for the reasons that follow, the phosphorus fed during the dry period has been varied rather than the calcium.

The results of certain metabolism experiments in which the calcium and phosphorus balances have been followed—particularly those of Forbes (5) and Hart (8)—seem to show that calcium and phosphorus metabolism are largely independent of each other. In these experiments, however, the calcium and phosphorus balances were not followed for more than 20 days successively. There is no reason to doubt the figures that have actually been obtained, and it is very likely that a cow may lose 200 or 300 grams of calcium while remaining in phosphorus equilibrium. But it is doubtful whether the metabolic independence of the two elements ever goes much further than this. In a recently published article this question was discussed in some detail, and it has been pointed out that the weight of evidence obtained from carcass analyses is strongly against the view either that the ratio of calcium to phosphorus in bone is subject

[4] Our evidence shows only that cows are not kept up to their optimum milk yield when fed the protein and total nutriment required by the standards in the form of the amounts of grain, hay, and silage used on the Beltsville farm. The reader must judge for himself how closely this method of feeding approaches what is typical throughout the country.

to more than very small variations or that the concentration of either of these elements contained in any of the soft tissues undergoes more than insignificant changes. Evidence has also been adduced to indicate that calcium assimilation in cows is likely to be seriously interfered with for a period of at least eight days by the mere collection of their urine and feces by attendants as practiced in the experiments of Forbes, of Hart, and of ourselves (13).

It is likely, therefore, that any considerable deficiency of either calcium or phosphorus in the rations of a milking cow will bring about the loss of both elements from the animal's bones if continued for more than two or three weeks, and that a cow which has suffered from the lack of either during any considerable part of her lactation period will find herself depleted in both when she reaches the end of that period.

In recently published articles from this laboratory (12) (13) it has been shown that the phosphorus content of the blood plasma of cows is highly variable, and that it is likely to be low in the plasma of the Beltsville herd toward the end of their periods of pregnancy. This suggests that the cows of the Beltsville herd usually reach the end of their lactation period with their phosphorus stores depleted, and that the rations fed during the dry period are not sufficient to restore them. For the reasons which have been given it is likely that the calcium stores of the Beltsville cows are also depleted during their lactation periods, and that neither the calcium nor the phosphorus stores can be restored to their proper level during the dry period unless the cows are fed rations which make it possible for them to assimilate liberal quantities of both elements.

In the articles just mentioned, certain other facts regarding calcium and phosphorus metabolism were brought to light. It was shown that the concentration of calcium in cows' blood plasma is much more constant than that of phosphorus. It is usually easy to raise the concentration of plasma phosphorus by increasing the amount of phosphorus in the rations—either by feeding more grain or by adding sodium phosphate to the ration. But the changes, brought about in the concentration of plasma calcium by analogous procedures or by any other influences that we have encountered so far, are comparatively insignificant and usually fall within the limits of error of our determinations.

It has seemed likely, therefore, that changing the amount of phosphorus in the ration would have more immediate and easily determinable effect on the changes which go on in a cow's udder shortly before her calf is born than changing the amount of calcium. The experiments herein reported were planned with this idea in mind. But it was essential that both the control and the experimental ani-

mals should have plenty of calcium in their rations, and therefore all received alfalfa hay in quantities which it was hoped would provide sufficient calcium.

The details of the experimental procedure and the results obtained are given in the description and tables at the end of the article.

The experiments consisted essentially (*a*) in drying cows off about 60 days before they were due to calve, (*b*) in feeding the controls a certain basal ration, (*c*) in feeding the others the same basal ration, giving grain and hay on alternate days and adding sodium phosphate to the grain, and (*d*) in following the milk yields from the tenth to the fortieth day after calving.

Some of the animals used in the experiments were from the general herd, and had previously been fed approximately according to the Savage feeding standard. Others had been on test during the year preceding the experiments, and had been fed much more liberally. In the case of the animals from the general herd (see Tables 1 and 2) the alternated feeding with phosphate had a very favorable influence on the subsequent milk yield; but in the case of those which had been on test (Table 3), the effect was insignificant. This indicates that the rations fed to the general herd were deficient in one or both of the principal bone-building elements.

The results show that the effect of the alternated feeding with phosphate on the subsequent milk yield will depend on the previous history of the cows as well as on the amount of phosphorus contained in the basal ration. It follows that the quantitative results of the experiments are significant only for the special conditions under which they were carried out. They might be entirely different in a herd whose previous history had been different, or with a basal ration which contained a different amount of phosphorus.

The attempt has been made, however, to get an approximately quantitative idea of the increase in milk yield produced by the phosphate feeding under the conditions of experimentation used with the cows of the general herd. For this purpose, only those animals have been considered which figure both as controls and as experiment animals and whose histories are given in Table 1. The method and results used in this attempt are given in Table 8 with its appended comment and in figure 3. The animals gave, on the average, 37.9 per cent more milk after the phosphate feeding than would have been expected from their previous performance.

The milk yield from the tenth to the fortieth day after calving has been taken as the most important measure of the effect produced by the alternated feeding with phosphate during the preceding dry period. But certain other aspects of the effect produced by this treatment have also been studied.

Both the animals on the experimental feeding and those used as controls were weighed from time to time. We do not wish to lay too much stress on the results obtained, because the manner in which an animal gains weight in the period of a month or so before it calves depends almost as much on its previous history as on the ration fed at the time. The results in question are given in Tables 4, 5, 6, and 7. They are rather irregular, but indicate, on the whole, that the animals on alternated feeding with phosphate made somewhat better gains than the controls.

In a previous publication from this laboratory (13) a balance experiment was described in which the animals received alternated rations with phosphate for a part of the time. The alternated feeding with phosphate had no perceptible effect on the amount of urine or feces voided or on the water content or consistency of the feces.

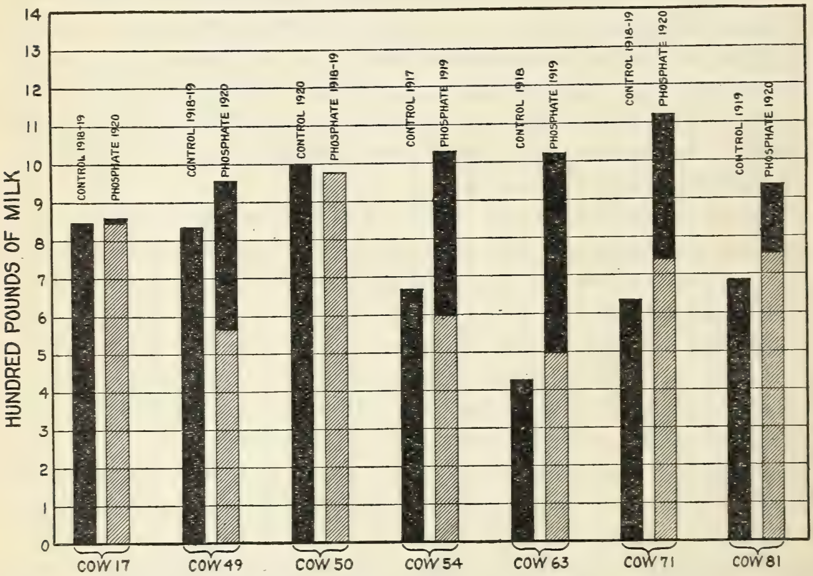

FIG. 3.—Comparison of milk yields of cows from the general herd after control and phosphate feeding. The columns show the amounts of milk given in 30 days soon after calving; the lighter portions of the columns show the amounts of milk to be expected after the phosphate feeding, using the yields after the control feeding as a basis, and taking into account the facts that some of the animals aborted and that the younger ones would show the increase normally occurring with the second calf (see pp. 24 and 25) during the experimental feeding.

We have the impression that the increase in size of the udder which occurs before calving has generally appeared earlier and has been more marked in the animals which have received the phosphate than in the controls. There have, however, been exceptions to this rule, and we do not feel inclined to insist very strongly upon it. We realize keenly the difficulty of judging accurately where no exact measurements are taken.

DISCUSSION OF RESULTS.

Our results indicate that the milk yield of the general herd at Beltsville has been reduced by an insufficiency either of calcium or of phosphorus, or of both, in the rations, in spite of the facts that these contained more than the average proportions of both calcium and phosphorus and were fed in the amounts required according to the feeding standards. We think it is still an open question whether calcium or phosphorus has been the element chiefly lacking, and whether the rations could be improved from the standpoint of mineral nutrition by varying the proportions of the different feeds used. Work aimed to throw light on these problems is now being carried out here. In the meantime, however, it seems worth while to consider what the knowledge already at hand indicates ought to be done.

Table 1 contains the cases where a cow s record after the phosphate feeding is compared with a previous record of her own made after a period on the basal ration. It will be noted that in most of these cases the basal ration was fed before the first calf was born. The results as given in this particular table, therefore, are chiefly evidence for the view that the heifers received insufficient calcium or phosphorus in the rations supplied to them before they had their first calves.

We believe that this was the case, and we shall later discuss the rations supplied to the heifers which had never had calves. But the records for the general herd indicate that, under the Beltsville routine, the animals never recovered from the mineral shortage which made itself evident in the first lactation period.

The evidence from the records which indicates this may be summed up as follows: In the case of the animals born at Beltsville and kept under the routine treatment there was no tendency for the milk yield to rise after the first lactation period to the extent that it did in the cases of cows 54, 63, 71, and 81, shown in Table 1. The rise as between the first and subsequent lactation periods was approximately that which would be expected from the data collected by Pearl and Patterson (14) and by the Holstein and Guernsey breeding associations. In the case of animals brought to the farm from other places and kept under the routine treatment, there was frequently a tendency for the milk yield to fall off more rapidly than it should with advancing age, as in the cases of cows 17 and 201, figures 1 and 2.

As many of the cows which received the alternated rations with phosphate received a basal ration somewhat lower than that fed to the general herd during their dry periods, it is fair to compare the milk yields of these two sets of animals. Cows 49, 54, 71, and 81 may be taken as representing the effects of the phosphate feeding in the

case of grade Guernseys. In a period of 30 days soon after calving, these animals gave 1,009 pounds of milk on the average. Their records may be compared with those of the other grade Guernseys of the herd, selecting lactation periods later than the first and in which there was no suspicion of abortion or other disturbing disease, and using the best month's milk yield in each lactation period as the figure to be compared with that given above. There are 4 animals with a total of 8 lactation periods available for the comparison, and the average best month's milk in the 8 lactation periods was 660 pounds. As the grade Guernseys available for this comparison were rather few, the same calculation was made for the grade Jerseys. There are 16 animals with 52 lactation periods available in this case. The average best month's milk is 722 pounds. The grade Holsteins are not sufficiently numerous to give figures of any value.

No cow among the grade Jerseys and Guernseys of the general herd has ever surpassed the 30-day record of cow 71. In only one case has the average 30-day record given for cows 49, 54, 71, and 81 after the phosphate feeding, been surpassed, namely, with a best month's milk yield of 1,041 pounds given by one of the grade Jerseys. In only five cases has the lowest 30-day record among these four cows been surpassed, namely, by best month's milk yields of 1,041, 988, 987, 1,004, and 943 pounds, respectively.

The results show, therefore, that the cows of the general herd at Beltsville suffered from an insufficiency of either calcium or phosphorus, or both, in their rations throughout their lives, both before their first calves were born and afterwards. The following shows a little more in detail than has been done heretofore how they were fed.

The young stock generally received milk until the animals were six months old or more. The feeding of grain, hay, and silage, however, was started before the end of the first month and gradually increasing quantities of these feeds were given until at the end of six months the calves were taking 3 pounds of grain, 3 pounds of legume hay, and 10 to 20 pounds of corn silage. After they were taken off milk the calves were usually fed 3 pounds of grain, 3 pounds of legume hay, and as much corn silage as they would clean up. The grain mixture most used was grain mixture E. If they ate 25 pounds of corn silage daily, which may be taken as a fair average, this ration would supply 0.94 pound digestible protein daily and 8.16 pounds total digestible nutriment. This is approximately the protein requirement given in the Wolff-Lehmann feeding standards for growing dairy cattle and somewhat more than the requirement for total nutriment (10).

The manner in which the cows were fed and treated subsequent to the birth of their first calves has already been discussed at some length (pp. 1 to 3). It is only necessary to add a word about the actual amounts of grain, hay, and silage given. The manner in which the mature dry cows were fed has already been given (p. 2). The mature milking cows were generally fed 1 pound of grain mixture B or C to each 3 pounds of milk given, 6 to 8 pounds of legume hay, and as much corn silage as they would clean up. They usually gave about 25 pounds of milk a day when they were fresh and at this period they commonly got 8 pounds of grain mixture B, 8 pounds of legume hay, and 30 pounds of corn silage. They usually got a little thin with the progress of their lactation and were then fed somewhat more grain in proportion to the milk yield. In the course of the year, as has already been stated, they got a little more protein and total nutriment than is required by the Eckles or Savage feeding standards.

The bone-building elements can probably be supplied in sufficient quantity in two different ways—either by feeding the ordinary materials much more liberally than the feeding standards require or by adding calcium and phosphorus in the form of inorganic salts directly to the rations. We are confident that the latter method will finally be adopted and will effect a great saving in the cost of producing milk.

But so radical a change in feeding practice ought, perhaps, to be introduced slowly and with caution; the more conservative dairyman will probably prefer to keep to the ordinary farm feeds until the effects of feeding inorganic salts of calcium and phosphorus have been more fully worked out by the experiment stations.

Our experience at Beltsville indicates that with many cows a liberal ration fed for 4 to 6 weeks before calving easily pays for itself through the increased flow of milk in the subsequent lactation period, and we think that there are many cows throughout the country which are far more valuable than their owners suppose them to be. Those dairymen who have been feeding their animals according to the standards or less should try giving each cow a period of two months dry and feeding her during that period three or four times the protein and two or three times the total nutriment required for maintenance. The feeds used should contain plenty of calcium and phosphorus—legume hay and a liberal proportion of bran and cottonseed or linseed meal. If dairymen find that the milk yield of any of their cows is doubled by this process, they will run no risk of reducing their profits by feeding those cows even 50 per cent more

nutriment in the course of the year than the feeding standards call for.[5]

There is one other aspect of the case which must be discussed. Quite apart from the question of the feed cost per pound of milk when a cow's yield is reduced by feeding a ration deficient in one or more necessary constituents, is the question of the effect of this process on her capacity to resist disease. The Beltsville herd has suffered severely in the last three years from contagious abortion. The relation between the incidence of this disease and the manner in which the cows have been fed is being carefully studied at present, and the results of this study will be reported later. The results already obtained, however, are sufficient to justify a strong suspicion that abortion has occurred more frequently among the animals that were less adequately fed. But, whatever the final results of this study may be, it is obviously bad practice to allow a cow to deplete her body stores of important materials for long periods of time, even though milk may thereby be temporarily more economically produced. The ideal method is clearly to keep the yearly supply of raw materials in the food equal to the demand for milk production.

SUMMARY.

Feeding cows for several years according to the commonly accepted standards with little or no additional pasture, has resulted in their milk yield being reduced much below the optimum. The condition of reduced milk yield so brought about may be corrected by giving the animal a dry period of two months, and feeding during that period a ration containing legume hay and grain with a high phosphorus content and with three or four times the amount of protein required for maintenance, and two or three times the total nutriment. The milk yield in the subsequent lactation period may sometimes be doubled by this treatment.

In the case of cows of which the milk yield has been reduced by several years' standard feeding, a greatly increased yield can be brought about by feeding "alternated rations with phosphate" during the dry period. This is taken to mean that the ordinary rations are more likely to be deficient in one or both of the principal bone-building elements than in any other constituent.

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[5] Feeding cows heavily before they calve, of course, introduces the risk of milk fever. But if this disease is properly treated, the mortality is not high and there are apparently no enduring bad effects. A well-managed dairy farm should be equipped for dealing with milk fever. Our experience at Beltsville shows that the risk even of the appearance of the disease is not very great. In the last five years there have been something over 30 cases of cows fed two to four times the maintenance requirement of protein and total nutriment before they calved, and milk fever has appeared only twice. One of these cases was in a young cow, but was mild; the other was in a cow 15 years old.

DESCRIPTION OF EXPERIMENTS, PROTOCOLS, AND TABLES.

EFFECTS, ON MILK YIELD, OF LIBERAL FEEDING DURING DRY PERIOD.

Cow 17, a grade Jersey, was born in 1909 and brought to the Beltsville farm in 1912. The protein and total nutriment contained in her rations during the years 1914, 1915, 1916, and 1917 were calculated and compared with the quantities required for her maintenance and for her milk and fat yield according to the Savage standard (9), and it was found that she received on the average a surplus of about 10 per cent of protein and about 2 per cent total nutriment. It may be considered, therefore, that she was fed as nearly according to this standard as is possible under any ordinary conditions. She was on pasture for only 7 days during the four years under consideration. She had a calf toward the end of the summer of each year; the 1917 calf was born six weeks ahead of time, but it survived and was alive and well in June, 1920. The other three calves were all born at term. Her dry periods were 44 days on the average.

In 1914 she gave 5,709 pounds of milk; in 1915, 5,121 pounds; in 1916, 5,056 pounds; in 1917, 4,693 pounds; and in 1918, 2,569 pounds.[6] In 1918 she was given a dry period of 122 days, with approximately the same ration as in previous dry periods. She calved December 11, 1918, and her milk yield for 1919 rose to 5,578 pounds.

During her dry periods in 1914, 1915, and 1917, she was fed 4 pounds of grain mixture B, 4 pounds of legume hay, and 30 to 35 pounds of corn silage. During her dry period in 1916 she received 4 pounds of grain mixture B, 3 pounds of oat hay, 28 pounds of corn silage, and had 7 days on pasture. During the last 53 days of her 1918 dry period she was fed 4 pounds of grain mixture C, 4 pounds of legume hay, and 30 pounds of corn silage. Her milk yields for the first clear month after calving in each of the five years under consideration were as follows: October, 1914, 799 pounds; September, 1915, 731 pounds; September, 1916, 690 pounds; November, 1917, 416 pounds; and January, 1919, 873 pounds.

The milk yield for the first six weeks after calving is not markedly influenced by moderate changes in the feed supplied (2), and the rations given in the months mentioned above were so nearly equivalent that they could not have produced the observed differences in the milk yield. These are to be attributed, therefore, to the nutritive condition of the cow in her dry periods. The large yield for January, 1919, is the result of the long dry period with a ration considerably above the maintenance requirement.

Cow 201, a purebred Holstein, was born March 13, 1905, and brought to Beltsville in 1912. The protein and total nutriment con-

[6] This very low yield is partly explained by the facts that the cow aborted in 1917 and that she had an unusually long dry period in 1918.

tained in her rations during the years 1914, 1915, 1916, and 1917 were calculated and compared with the quantities required for her maintenance and for her milk and fat yield according to the Savage standard, and it was found that she received, on the average, a surplus of about 8 per cent protein and about 9 per cent total nutriment. She was on pasture for 46 days during the four years under consideration. She calved normally in the autumn of each year. Her dry periods were 50 days on the average.

In 1914 she gave 12,182 pounds of milk; in 1915, 8,269 pounds; in 1916, 7,224 pounds; in 1917, 5,708 pounds; and in 1918, 4,796 pounds. In 1918, she was given a dry period of 78 days, and, during the last 40 days of this period, was fed a much more liberal ration than during her previous dry periods. She calved October 30, 1918, and her milk yield for 1919 rose to 8,711 pounds.

During her dry periods in 1914, 1915, 1916, and 1917 she was fed approximately the same rations as those fed to cow 17 in her corresponding dry periods. During the last 40 days of her 1918 dry period she was fed daily 11 pounds of grain mixture C, 11 pounds alfalfa hay, and 26 pounds corn silage. Her milk yields in pounds for the first clear month after calving in each of the five years under consideration were as follows: December, 1914, 1,138 pounds; October, 1915, 1,230 pounds; October, 1916, 896 pounds; October, 1917, 579 pounds; December, 1918, 1,293 pounds.

For the same reasons as have been given in the case of cow 17, the greatly increased milk yield after the 1918 calving is to be attributed to the more liberal ration fed in the 1918 dry period. It should be mentioned that this cow was milked three times a day during December, 1918, and only twice in the other months above recorded. But the increase in milk yield to be expected from this change in treatment has been much studied at Beltsville; it could hardly have been more than 10 per cent in a case such as that under consideration. The actual increase as between October, 1917, and December, 1918, was more than 120 per cent.

EFFECTS, ON MILK YIELD, OF FEEDING PHOSPHATE WITH ALTERNATED RATIONS DURING DRY PERIOD.

These experiments may be generally described as follows: Cows were dried off about two months before they were due to calve and were fed, during their dry periods, a basal ration containing 3 to 6 pounds of grain, 4 to 5 pounds of alfalfa hay, and 30 pounds of corn silage. Half of the animals were used as controls and were fed the basal rations without supplement. The others received the same basal rations supplemented with sodium phosphate, the grain and hay of the rations being fed on alternate days. In many cases the same

animal served as a control one year and as an experiment animal the next year. In a typical experiment an animal would receive daily for 60 days before calving 3 pounds of grain mixture C, 4 pounds alfalfa hay, and 30 pounds corn silage. The next year she would receive in the corresponding period the same average daily quantities of the same feed, but instead of receiving equal amounts of all the feeds every day, she would receive on one day no grain, 8 pounds of alfalfa hay, and 30 pounds corn silage, and the next day 6 pounds of grain with sodium phosphate added to it, no hay, and 30 pounds of corn silage. For the sake of brevity the first procedure will be spoken of as the "control feeding," the second as the "experimental feeding" or the "alternated feeding with phosphate."

The animals which received the phosphate were fed alternated rations, as above described, with the idea of separating to some extent the calcium and phosphorus compounds in the intestinal tract. There is a good deal of evidence to show that the absorption of phosphorus from the intestinal tract may be hindered by the simultaneous presence of calcium compounds (1), (4), (7). As the hay contains most of the calcium of the rations, and the grain most of the phosphorus, the experimental animals received an excess of calcium one day and an excess of phosphorus the next. When the average daily ration was 3 pounds of grain mixture CP, 4 pounds alfalfa hay, and 30 pounds corn silage, they received about 61 grams of calcium and 17 grams of phosphorus on the days when they were fed hay; and about 16 grams of calcium and 50 grams of phosphorus on the grain days.

After calving, the controls and experiment animals were fed alike or according to their milk yields. As the milk yield for the first five or six weeks after calving is not much influenced by small changes in the contemporaneous food supply (2), we have not thought it necessary to give a detailed account of how the cows were fed during this period.

The milk and fat yields of the control and experiment animals were followed for the first 40 days after calving, and, as a rule, the milk produced from the tenth to the fortieth day after calving was taken as a measure of the effect of the alternated feeding with phosphate. In many cases the body weights of the animals were also followed during the periods when they were on the control or the experimental feeding.

It was decided to use sodium phosphate as the mineral supplement, partly in order to study the effects of phosphorus as distinguished from calcium, partly because the phosphates of sodium are much more soluble in neutral solutions than any of the phosphates of calcium, and it was judged that feeding the more soluble salts would produce the maximum effect of the phosphorus on metabolism. Di-

sodium phosphate (Na_2HPO_4) was selected because it is the most nearly neutral of the various sodium salts. A very pure preparation of this compound, containing 9 to 12 molecules of water of crystallization,[7] can be obtained commercially at about $100 per ton.

Sodium phosphate has been fed in only a few of the numerous phosphate-feeding experiments which have been conducted in the past. Gouin and Andouard (6) worked with it to some extent, but they gave no information in regard to the particular sodium phosphate used or in regard to its water content. If we understand them right, their doses were very small in comparison to those which we finally used. We began with doses of 4.5 grams of phosphorus as di-sodium phosphate daily, and finally gave doses of 24 grams without producing any noticeable digestive disturbances.

In deciding on the basal ration to which the phosphate was to be added we were largely influenced by the fact that the dry cows at Beltsville had previously been fed, as a matter of routine, a ration consisting of 4 pounds grain,[8] 4 pounds legume hay, and 30 pounds corn silage.

This ration carries decidedly more than enough protein and total nutriment to provide for the maintenance of a 1,000-pound cow, according to the Haecker and Savage standards (9); and according to the results obtained by Eckles (3), the surplus should be sufficient to provide for the development of the unborn calf. Using a slightly less liberal feed for the basal ration made it possible to compare the performance of the cows fed phosphate in addition with that of the general herd. In several cases, however, a somewhat more liberal ration was used both for the control and for the experimental animals.

Alfalfa was selected as the hay to be used, partly on account of its high calcium content and partly because it had been used at Beltsville in the past as often as anything else.

The experiments fall into two general classes: First, those on animals which had been fed for some years previously according to the routine used for the general herd; and, second, those on animals which had been on test and which, for at least a year preceding our experiments, had been fed much more liberally than the general herd. In the first class there are two smaller groups. Group 1 consists of seven experiments where the same animal served in one year as control and in another as experiment. Group 2 consists of experiments in which the records of animals on the phosphate feeding were

[7] The salt crystallizes with 12 molecules of water, but loses a considerable part of its water of crystallization readily on exposure to air. As obtained commercially, therefore, it generally contains less than 12 molecules of water.

[8] The grain mixture fed has been varied from time to time. Those most frequently used were grain mixtures B and C. The protein, total nutriment, and mineral content of these are fairly typical for all the other mixtures.

compared with those of other approximately similar animals used as controls.

The data in the case of the animals which had been on test are rather complicated. In our experiments all these animals were dried off 60 days or more before they were due to calve and were fed during this period on a basal ration of 3 pounds grain mixture D, 5 pounds alfalfa hay, and 30 to 35 pounds corn silage. The controls received this ration fed in the usual way and without any supplement. The others received grain and hay on alternate days and with phosphate added to the grain. It would be possible to compare the experiment animals directly with the controls in this series, but as they are not exactly comparable and as the cases are few we have thought it better to take into account the past records of both controls and experiment animals. We have, therefore, compared the performance of each animal, after either control or phosphate feeding, with her performance in the preceding year and determined whether the phosphate or control performances compare the more favorably with the preceding performance of the same animal.

For several years before the experiments began the cows from the general herd, of which the histories are tabulated in Tables 1 and 2, were fed approximately according to the Savage standard. They received on the average about 0.25 pound protein and 1 pound total nutriment more daily than this standard calls for. The building of the calf annually is not taken account of in this calculation, but the yearly 91 pounds protein and 365 pounds total nutriment received over and above what the standard calls for should have provided sufficiently for this process, according to Eckles's results (3).

The manner in which the test cows were fed contrasts strongly with the above method. During the year in which they were on test and actually milking these animals received a daily average surplus of 1 to 1.5 pounds protein and about 4 pounds total nutriment. For a number of weeks before they calved they received the enormous daily surplus of about 4 pounds protein and 16 pounds total nutriment. In other words, the ration fed before calving in preparation for the test contained about six times as much protein and about three times as much total nutriment as is required for maintenance. In the course of a year, taking into account the dry period before going on test, these animals received about 100 per cent more protein and about 50 per cent more total nutriment than is called for by the Savage standard.

It will be noted that the character of the experiments has made it necessary to keep the animals under observation for periods of more than a year, and to use the milk yield as a measure of the results to be studied. In the course of a year innumerable small things, which

are quite beyond experimental control but which might have some influence on milk yield, happen to a cow—weather changes and small disturbances in health and appetite are examples of such incidents. To report them, even to the extent to which they have been recorded in our notes, would be quite impracticable on account of the space required. We have, therefore, given only such features of the histories of the cows as might have an influence on the milk yield of the same general order of magnitude as the differences which have commonly been observed as the result of the phosphate feeding.

The manner in which the animals were fed before calving in our experiments is given below, and the tables give such data regarding the experiments as can be conveniently tabulated.

RATIONS GIVEN ANIMALS BEFORE CALVING.

ANIMALS FROM THE GENERAL HERD.

Cow 17, 1918.—September 25 to October 18, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. October 19 to December 11, 4 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 17, 1919–20.—November 26, 1919, to February 14, 1920, alternated rations with daily average of 3¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage. February 15 to March 29, 1920, alternated rations with daily average of 4¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 21, 1918.—August 28 to November 30, alternated rations with daily average of 6 pounds grain mixture CP_1, 5 pounds alfalfa hay, 30 pounds corn silage.

Cow 49, 1918.—October 31 to December 1, 4 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. December 2 to 25, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 49, 1919–20.—December 12, 1919, to January 14, 1920, alternated rations with daily average of 4¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 50, 1918.—October 2 to December 20, alternated rations with daily average of 5 pounds grain mixture CP_1, 4 pounds alfalfa hay, and 30 pounds corn silage. From October 4 to 9, 85 grams calcium carbonate were added daily to the silage on the days when hay was fed; from October 10 to December 20, 158 grams.

Cow 50, 1920.—April 2 to June 3, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 54, 1917.—March 14 to May 14, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 54, 1919.—May 8 to June 2, alternated rations with daily average of 3 pounds grain mixture CP_1, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 59, 1917.—October 26 to December 26, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 63, 1917–18.—December 1, 1917, to February 1, 1918, 3 pounds grain mixture C, 8 pounds corn stover, 30 pounds corn silage.

Cow 63, 1919.—February 3 to March 10, alternated rations with daily average of 3 pounds grain mixture CP_1, 4 pounds alfalfa hay, 24 to 30 pounds

corn silage. March 11 to 28, 3 pounds grain mixture C, 4 pounds alfalfa hay, 24 pounds corn silage; rations not alternated. March 29 to April 25, same as for February 3 to March 10.

Cow 64, 1918–19.—December 19, 1918, to January 5, 1919, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. January 6 to February 6, 1919, 6 pounds grain mixture C, 5 pounds alfalfa hay, 30 pounds corn silage.

Cow 67, 1918.—April 1 to 20, alternated rations with daily average of 3 pounds grain mixture CP_2, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 70, 1918–19.—October 19, 1918, to January 27, 1919, alternated rations with daily average of 3 pounds grain mixture CP_1, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 71, 1918.—September 25 to December 1, 3 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage. December 2 to 11, 5 pounds grain mixture C, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 71, 1919–20.—December 20, 1919, to February 20, 1920, alternated rations with daily average of 3¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage. February 20 to March 1, 1920, alternated rations with daily average of 5¼ pounds grain mixture CP, 4 pounds alfalfa hay, 30 pounds corn silage.

Cow 81, 1919.—February 24 to April 24, 1919, 3 pounds grain mixture E, 3 pounds alfalfa hay, 30 pounds corn silage, 5.7 grams calcium as calcium chlorid daily.

Cow 81, 1920.—February 13 to April 6, alternated rations with daily average of 3¼ pounds grain mixture CP, 3 pounds alfalfa hay, 30 pounds corn silage.

Cow 213, 1918.—January 1 to February 6, 5.6 pounds grain mixture C, 3 pounds soy-bean hay, 8 pounds corn stover, 25 pounds corn silage.

Cow 214, 1918.—March 28 to May 6, alternated rations with daily average of 3 pounds grain mixture CP_2, 4 pounds alfalfa hay, 30 pounds corn silage. May 7 to 15, alternated rations with daily average of 5 pounds grain mixture CP_2, 4 pounds alfalfa hay, 30 pounds corn silage. May 16 to 27, alternated rations with daily average of 5 pounds grain mixture CP_1, 4 pounds alfalfa hay, 30 pounds corn silage.

ANIMALS WHICH HAD BEEN ON TEST DURING THE YEAR PRECEDING THE EXPERIMENTS.

For a month or so before they calved previous to the test lactation period these animals were fed daily rations of from 8 to 18 pounds of grain mixture F, 10 to 16 pounds alfalfa hay, and 24 to 30 pounds corn silage. The grain mixtures fed contained more protein and ash than either grain mixture C or D. The rations supplied a great excess of both protein and total nutriment above the maintenance requirements.

After they had finished their tests, these animals were dried off about two months before they were due to calve. Cows 227, 232, and 240 were selected as controls and were fed 3 pounds grain mixture D, 5 pounds alfalfa hay, and 30 pounds corn silage for 60 days before calving. Cows 228, 229, and 248 served as experimental animals. For 60 days before calving they were fed alternated rations with a daily average of 3½ pounds grain mixture DP, 5 pounds alfalfa hay, and 30 pounds corn silage.

CONDENSED HISTORY OF THE EXPERIMENTAL ANIMALS.

TABLE 1.—*Animals from the general herd used both as experiments and controls.*

No. of animal.	Date of birth.	Breed.	Date of calving. After control feeding.	Date of calving. After phosphate feeding.	Days dry. Control period.	Days dry. Phosphate period.	Milk yield.[1] After control feeding.	Milk yield.[1] After phosphate feeding.	Fat yield.[1] After control feeding.	Fat yield.[1] After phosphate feeding.
					Days.	*Days.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
17	1909.	Grade Jersey..	Dec. 11, 1918	Mar. 29, 1920	122	122	847	858	33.9	33.5
49	Oct. 22, 1914	Grade Guernsey.	Dec. 25, 1918	Jan. 14, 1920	71	36	831	953	40.7	43.8
50	Oct. 25, 1914	Grade Holstein	June 3, 1920	Dec. 20, 1918	73	98	995	972	38.8	38.9
54	Jan. 22, 1915	Grade Guernsey.	May 14, 1917	June 2, 1919	First calf.	61	669	1,027	24.1	34.9
63	Oct. 17, 1915	Grade Holstein	Feb. 1, 1918	Apr. 25, 1919	..do..	103	422	1,018	15.5	34.1
71	July 15, 1916	Grade Guernsey.	Dec. 11, 1918	Mar. 1, 1920	..do..	60	632	1,121	29.1	49.3
81	Feb. 19, 1917	.....do........	Apr. 24, 1919	Apr. 6, 1920	..do..	44	685	936	26.0	42.1

[1] The figures given in these columns represent the number of pounds of milk and fat given from the tenth to the fortieth day after calving, except in the case of cow 54. In this case it was necessary to take the figures for the yields from the eighteenth to the forty-eighth day after calving, as the daily milk records from the tenth to the seventeenth day in 1917 had been lost.

The following comments are made on the animals in Table 1:

Cow 17.—This animal gave very little more milk after the phosphate feeding than after the control feeding. She had a long dry period in both cases. It seems likely that the long dry period enabled her to restore any insufficiency of bone material which may have existed at the beginning of the experiment. She had a uterine infection after the experimental feeding, which may have reduced her milk somewhat in the experimental period.

Cow 49.—This animal aborted during the period of phosphate feeding 39 days before term. The abortion greatly shortened her dry period on the phosphate feeding and prevented her receiving the more liberal grain ration which she had eaten for 23 days before calving during the control period. In the general herd, abortions 5 weeks or more before term have decreased the first two months' milk yield from 30 to 50 per cent. We have no way of accounting for the increased milk which was given in this case after the abortion, except as the result of the phosphate feeding.

Cow 50.—This animal was fed a much more liberal grain ration than the others in both the control and experimental periods. She "leaked" milk from her udder to a considerable extent through the experimental period, and she had a uterine infection after calving in the control period, which may have somewhat reduced her milk yield. She gave a little more milk in the control period than in the experimental period. The numerous disturbing circumstances make it difficult to interpret the results, but they seem to us to indicate that often the addition of phosphate will have little effect when the basal grain ration is as high as 5 pounds daily.

Cow 54.—This cow aborted during the phosphate feeding 28 days before term. Judging from the history of such cases in the general herd, her milk yield should have been about 10 per cent less than after the control feeding. We have no way of accounting for the actual increase except as the result of the phosphate feeding.

Cows 63, 71, and 81.—The remaining three animals of Table 1 were fed on the control rations before their first calves were born and on the experimental rations before their second calves were born. It is well known that heifers are likely to give more milk with their second than with their first calves; the average increase has been worked out by Pearl and Patterson (14) for Jerseys, and the department has figures obtained from the cow-testing associations for Guernseys and Holsteins. In Table 8 we have given the actual and expected increases; in calculating the expected differences we have in each case used the set of figures which would give the largest differences, in order to avoid any possible suspicion of favoring the results of the phosphate feeding. The milk yield of all three heifers increased after the phosphate feeding decidedly more than would be expected as the result of age alone. We have no way of accounting for the additional increases except as the result of the phosphate feeding.

TABLE 2.—*Animals from the general herd used only either as experiment or control animals.*

CONTROLS.

No. of animal.	Date of birth.	Breed.	Date of calving.	Days dry.	Milk yield.[1]	Fat yield.[1]
				Days.	*Pounds.*	*Pounds.*
59	Aug. 10, 1915	Grade Holstein	Dec. 26, 1917	First calf	568	20.5
64	Oct. 18, 1915	do	Feb. 6, 1919	62	1,108	40.1
213	Sept. 26, 1915	Holstein	Feb. 6, 1918	First calf	742	26.7

EXPERIMENT ANIMALS.

No. of animal.	Date of birth.	Breed.	Date of calving.	Days dry.	Milk yield.[1]	Fat yield.[1]
21	1907	Grade Jersey	Nov. 30, 1918	85	1,458	60.9
67	Dec. 29, 1915	Grade Holstein	April 20, 1918	First calf	753	26.3
70	April 22, 1916	Grade Guernsey	Jan. 27, 1919	do	588	28.3
214	Mar. 18, 1916	Holstein	May 27, 1918	do	1,554	46.8

[1] The figures given in these columns represent the number of pounds of milk or fat given from the 10th to the 40th day after calving.

The animals whose histories are tabulated in Table 2 were used in early experiments in which we were still feeling around for the conditions under which the effects of the phosphate feeding would stand out most sharply and in which the treatment of the subjects was not so carefully controlled as in the later experiments. The results, however, are in general accord with those of the later experiments, and it has seemed to us worth while to report them.

It would, perhaps, be fair to compare cow 59 with cows 67 and 70; cow 64 with cow 21; and cow 213 with cow 214. The figures for cow 59 represent approximately the average performance for the heifers of the general herd with their first calves. Cow 67 is a half sister of cow 59. The two animals have the same sire; the dam of 67 has a somewhat better record than that of 59. Cow 70 was selected in order to try the effects of phosphate feeding in an unfavorable case. Her mother had the poorest record of all the cows in the herd except two, and she herself was of unpromising appearance. Cow 64 was milked only twice a day; and cow 21 three times. The difference in the milk yields is, however, larger than is generally produced by this difference in treatment. Cows 213 and 214 were half sisters, both being daughters of the same sire. The dam of cow 213 had a decidedly better record than the dam of cow 214. Cow 213 was milked only twice a day, and cow 214 three times, but the difference in milk yields is very much greater than could be accounted for by this difference in treatment.

TABLE 3.—*Animals which had been on test during the year preceding the periods of control and phosphate feeding.*

No. of animal.	Date of birth.	Breed.	Date of calving.		Days dry.		Milk yield.[1]		Fat yield.[1]	
			Test period.	After control or phosphate feeding.	Before test period.	Control or phosphate feeding period.	Test period.	After control or phosphate feeding period.	Test period.	After control or phosphate feeding period.
			CONTROLS.							
					Days.	*Days.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
227	Aug. 2, 1915	Holstein	Apr. 18, 1918	Jan. 11, 1920	First calf.	137	1,674	2,019	61.8	83.8
232	Mar. 31, 1916	do	Nov. 29, 1918	Mar. 15, 1920	do	58	1,591	2,046	45.5	67.5
240	Nov. 10, 1914	do	Sept. 27, 1918	Feb. 9, 1920	59	112	1,876	1,881	64.2	80.9
			EXPERIMENT ANIMALS.							
228	Sept. 2, 1915	Holstein	Apr. 4, 1918	Dec. 30, 1919	First calf.	79	1,429	2,016	44.7	64.9
229	Nov. 8, 1915	do	May 28, 1918	Jan. 31, 1920	do	94	1,817	2,078	53.8	71.7
248	Mar. 15, 1916	do	Jan. 22, 1919	June 17, 1920	do	63	1,594	1,611	51.0	45.1

[1] The figures in these columns represent the milk and fat yields from the tenth to the fortieth day after calving, except in the case of cow 229. In her case they represent the milk and fat yields from the twentieth to the thirty-fifth day after calving multiplied by 2. It was necessary to take these figures instead of the usual ones, as she was sick for some days after calving in 1920, and suffered a severe cut in her rations, and she became sick again on the thirty-sixth day after calving.

It is not necessary to make any detailed comment on the results given in Table 3.

The differences in milk yield as between the cows fed phosphate and those fed the basal ration alone are so small as to be insignificant. It follows that the favorable influence of the phosphate feeding is

reduced to negligible proportions in the case of cows which have been superabundantly fed in their immediately preceding lactation period.

EFFECTS OF PHOSPHATE FEEDING ON BODY WEIGHT.

Both the animals on the experimental feeding and those used as controls were weighed from time to time. The results are given in Tables 4, 5, 6, and 7. These figures summarize all the pertinent results that we have. Heifers 67 and 214 were fed on the control rations in the late winter of 1917–18 and changed over to the experimental rations a few weeks before they calved. They, therefore, figure as controls in Table 4 and as experiment animals in Table 2. They were on the experimental feeding for such short periods that the weights obtained from them during those periods can not be used in the present discussion.

TABLE 4.—*Heifers on control rations; all four pregnant.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
67	20	1.75	Grain C	3	Alfalfa hay	4	Corn silage	30
71	60	0.65	do	3	do	4	do	30
81	180	1.04	Grain E	3	do	3	do	30
214	59	0.90	Grain C	3	do	4	do	25

TABLE 5.—*Heifers fed alternate rations with phosphate; No. 70 pregnant, No. 74 farrow.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Average daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
70	70	1.24	Grain CP_1	3	Alfalfa hay	4	Corn silage	30
74	80	2.20	do	3	do	4	do	30

TABLE 6.—*Cows fed control rations during dry periods before calving.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
17	50	1.38	Grain C	4	Alfalfa hay	4	Corn silage	30
50	59	1.76	do	5	do	4	do	30
51	47	1.28	do	3	do	4	do	30
64	60	1.32	do	6	do	5	do	30

TABLE 7.—*Cows fed alternated rations with phosphate during dry periods before calving.*

No. of animal.	Period during which weighings were taken.	Average daily gain.	Average daily ration.					
			Feed.	Quantity.	Feed.	Quantity.	Feed.	Quantity.
	Days.	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*
17	52	0.93	Grain CP	4¼	Alfalfa hay	4	Corn silage	30
21	80	1.57	Grain CP_1	6	do	5	do	30
50	30	2.50	do	5	do	4	do	30
71	30	1.87	Grain CP	3	do	4	do	30
81	31	1.03	do	3	do	3	do	30

It seems worth while to give in more detail the histories of two animals of which the weight changes on the experimental feeding were followed for comparatively long periods.

Heifer 74 was born October 15, 1916. From October 19, 1918, to January 15, 1919, she was fed alternated rations with phosphate, receiving as a daily average 3 pounds of grain mixture CP_1, 4 pounds alfalfa hay, and 30 pounds corn silage. She was farrow during this period. Her weights were as follows: October 24, 1918, 754 pounds; November 23, 1918, 804 pounds; December 23, 1918, 890 pounds; January 12, 1919, 930 pounds.

Cow 21 was born in 1907. From August 28 to November 30, 1918, she was fed alternated rations with phosphate, receiving as a daily average 6 pounds of grain mixture CP_1, 5 pounds alfalfa hay, and 30 pounds corn silage. She had calved November 7, 1917, and became dry September 6, 1918. She calved again November 30, 1918. During the period of phosphate feeding her weights were as follows: September 2, 1,027 pounds; October 2, 1,107 pounds; November 1, 1,143 pounds; November 21, 1,153 pounds.

Her best previous month's record for milk yield on the Beltsville farm was made in October, 1914, and amounted to 1,041 pounds. After this her milk yield gradually fell off; the best month's production after the 1917 calving was 469 pounds. She was in very good condition when she calved in 1918; in December, 1918, she produced 1,276 pounds of milk, and in January, 1919, 1,315 pounds.

These two cases show clearly that sodium phosphate may be fed to cows for long periods in large amounts without producing any deleterious effects on the digestive and assimilative processes.

QUANTITATIVE RESULTS.

In Table 8 and figure 3 an attempt is made to estimate how much the alternated feeding with phosphate increased the milk yield in the cows of the general herd under the conditions of our experiments. The column headed "Expected yield after alternated rations with

phosphate" gives the milk yields to be expected after the experimental feeding, using the yields after the control feeding as a basis and taking into account the facts that some of the animals aborted, and that the last four were heifers with their first calves in the control period and with their second or later calves in the experimental period. The figures represent the milk yield in 30 days beginning soon after calving.

TABLE 8.—*Expected and actual 30-day milk yields of cows from the general herd after alternated phosphate feeding: actual yields after control feeding.*

No. of animal.	Actual milk yield after control rations.	Expected milk yield after alternated rations with phosphate.	Actual milk yield after alternated rations with phosphate.
	Pounds.	*Pounds.*	*Pounds.*
17	847	847	858
49	831	565	953
50	995	995	972
54	669	599	1,027
63	422	495	1,018
71	632	739	1,121
81	685	753	936
Total	5,081	4,993	6,885

The actual yields after the alternated feeding with phosphate average 37.9 per cent more than the expected.

GRAIN MIXTURES USED IN EXPERIMENTS.[9]

GRAIN MIXTURE A.

Corn meal	45 pounds.
Wheat bran	36 pounds.
Cottonseed meal	18 pounds.
NaCl	1 pound.

GRAIN MIXTURE C.

Corn-and-cob meal	45 pounds.
Wheat bran	36 pounds.
Cottonseed meal	18 pounds.
NaCl	1 pound.

GRAIN MIXTURE CP_1.

Grain C	100 pounds.
$Na_2HPO_4 . 12H_2O$	10 pounds.

GRAIN MIXTURE D.

Hominy grits	45 pounds.
Ground oats	36 pounds.
Cottonseed meal	18 pounds.
NaCl	1 pound.

GRAIN MIXTURE B.

Corn meal	40 pounds.
Wheat bran	40 pounds.
Cottonseed meal	20 pounds.
NaCl	1 pound.

GRAIN MIXTURE CP.

Grain C	100 pounds.
$Na_2HPO_4 . 12H_2O$	11 pounds.

GRAIN MIXTURE CP_2.

Grain C	100 pounds.
$Na_2HPO_4 . 12H_2O$	6 pounds.

GRAIN MIXTURE DP.

Grain D	100 pounds.
$Na_2HPO_4 . 12H_2O$	19 pounds.

[9] The cottonseed and linseed meal used in these mixtures were meals from which the fat had been extracted by the old process—heat and pressure without solvents.

GRAIN MIXTURE E.

Corn-and-cob meal	55 pounds.
Wheat bran	30 pounds.
Linseed meal	15 pounds.
NaCl	1 pound.

GRAIN MIXTURE F.

Ground oats	28 pounds.
Linseed meal	20 pounds.
Cottonseed meal	10 pounds.
Gluten feed	14 pounds.
Hominy feed	14 pounds.
Wheat bran	14 pounds.
NaCl	1 pound.

ACCOUNT OF UNSUCCESSFUL AND INCOMPLETE EXPERIMENTS.

Many experiments on the effects of phosphate feeding were begun and then had to be abandoned because the animals aborted or failed to calve, or for other reasons. In other cases phosphate was fed to certain animals, but under rather different circumstances from those in the experiments which have been reported. We wish to mention briefly these unsuccessful and incomplete experiments partly because the results sometimes furnished interesting hints, partly in order to avoid any suspicion that the results reported for the successful experiments might be cases unconsciously selected in which the milk yield happened to be large after the phosphate feeding.

Several animals were started on the control rations, and subsequently either aborted or turned out to be sterile. It is not necessary to say anything about these further than that, in the cases where they aborted, the milk yields were such as would be expected from a consideration of their histories in comparison with those of the rest of the general herd.

Cow 63, whose 1918 and 1919 lactation periods have already been described in detail, was started again on the basal rations in 1920. She carried her calf to term, but acquired an acute general infection after she had been milking about two weeks, which rapidly reduced her milk yield to a very low point, and finally made it necessary to have her slaughtered. She began this lactation period, however, with a milk yield which promised to be as good as or better than that of 1919 after the phosphate period. It is to be remembered that her dry period in 1919 on the phosphate feeding was 103 days; and her dry period in 1920 was also about 100 days. We are inclined to think that these long dry periods made it possible for her to store up a good quantity of calcium and phosphorus, and it would not be surprising if the effect of the long dry period with phosphate feeding in 1919 lasted into 1920.

Several cows started on the phosphate feeding turned out to be sterile; and one aborted in addition to cows 49 and 54, whose histories have already been reported in detail. The abortion in question occurred at a period when it was the custom to remove aborting cows from the farm immediately, and before we realized that cows which

aborted after a period on the phosphate feeding might give more milk than they ever had before. We have no knowledge of the amount of her milk yield after the abortion.

Besides the cases so far reported, there are only seven animals which received any sodium phosphate at all. One of these received small daily doses (6.9 grams phosphorus as sodium phosphate) from the time she was born to when she dropped her first calf. She aborted with this calf, and gave a rather small quantity of milk subsequently. On account of the abortion and of the fact that the doses of phosphate were small, we do not think that this experiment throws any light at all on the question of the effects of phosphate feeding on the subsequent milk yield.

The six other animals received basal rations alone and then the same rations with phosphate added for short alternated periods, the main purpose of the experiments being to determine the effects of feeding phosphate on the concentration of phosphorus in the blood. Three of these happened to abort after periods of a week or more on rations without phosphate. They gave about the quantities of milk which would have been expected on the supposition that they had never had phosphate.

The other three dropped their calves while on the phosphate feeding. Two of them aborted after 7 and 10 days of phosphate feeding respectively. Both gave more milk than they ever had before, and decidedly more than would have been expected on the supposition that they had never had phosphate. The third was a heifer carrying her first calf. She calved normally at term after 26 days of phosphate feeding and gave much more milk than the general average for the herd with their first calves. These last three results suggest that even a short period of phosphate feeding may have a markedly favorable effect on milk yield if it occurs during the few days immediately before calving, during which the udder is rapidly enlarging in preparation for the coming lactation period.

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